SYMPOSIUM: A CLINICIAN'S GUIDE TO THE INTERNET

The Internet and Medicine: Past, Present, and Future

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The enormous growth of the Internet and the World Wide Web has made these two technologies an important potential adjunct to cost-effective health care research and delivery. This article surveys some recent developments in telecommunications, networking and artifical intelligence that are likely to have a significant impact on improving the efficiency and quality of future health care. Issues discussed include: clinical record keeping on the Internet, Internet-assisted medical diagnosis, privacy and security matters, financial transactions, digital money, bandwidth concerns, multimedia (music, audio and video) information delivery via the Internet, intellectual property, and the concept of Information Philanthropy.

INTRODUCTION

Few technological developments have had such an impact on communucation and information dissemination as the Internet and the World Wide Web. This empowering new technology is changing the way clinical medicine is practiced in a number of ways [1-8]. Some aspects of clinical care delivery which now involve the Internet include: (1) patient education and advocacy services, (2) continuing medical mducation (e.g., multimedia manuals of clinical procedures using graphical images and video clips), (3) telemedicine and, (4) digital agents and telediagnosis.

This article examines the evolution of the Internet and the nature of its clinical offerings from the collective perspectives of three physicians in academic clinical practice (anesthesiology and pain management). Emphasis is placed on recent technical developments on the Internet and the WWW we believe to be likely to have a lasting influence on health care delivery.

THE INTERNET IN THE PAST

Although most people think of the Internet as a recent development, its roots go back over two decades (Table 1). The Internet began with efforts on the part of the Advanced Research Projects Agency (ARPA) of the United States Department of Defense to produce a computer communications network (originally known as the ARPANET) that did not require a central control point, would automatically find a path around a disruption, and that would be reliable in wartime. Such a system would be less vulnerable to military sabotage or damage by nuclear attack. Over time, the technology developed for the

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[d]Abbreviations: See Glossary and Abbreviations in Appendix.

ARPANET was applied to create other networks, including one by NASA and the National Science Foundation's NSFNET. Each network imposed restrictions about the type of information that it could be used to transfer, depending upon who was funding the work and its final destination. To eliminate this "red tape," Congress created the National Research and Education Network, which was operated by Merit Communications for the NSF and had a strongly civilian, academic orientation. By the late 1980s, the Internet had become a global network connecting most universities and many businesses around the world. In 1993, when commercial providers were first permitted to sell Internet connections to individuals, usage of the network exploded. Millions of new users came on-line within months, and a new era of computer communications began.

Table 1: A Brief History of the Internet
(Primary source: Byte Magazine, July 1995)

1970	ARPANET starts with military support
1971	23 hosts; E-mail begins
1973	ARPANET extends to England, Norway
1974	BBN opens Telenet, a commercial version of ARPANET; 62 Hosts
1982	TCP/IP used for an "internet" of connected networks; 235 hosts
1983	500 hosts
1984	1000 hosts
1986	NSFNET established using a 56 Kbs backbone
1987	20,000 hosts
1988	Internet worm downs 6000 hosts
1989	NSFNET backbone now upgraded to T1 (1.544 Mbs); 100,000 hosts
1990	ARPANET vanishes
1991	WAIS (Wide Area Information Service) begins; University of Minnesota introduces Gopher Services; 600,000 hosts
1992	WWW (World Wide Web) release by CERN; One million hosts
1993	Whitehouse goes online (president@whitehouse.gov)
1994	Three million hosts; "Internet" is 25 years old
1995	Four million hosts; NSF decommissions NSFNET
1996	Netscape Navigator 2.0 released, supporting Java language and secure commercial Internet services
1997	Release 3.0 and 4.0 of Netscape Navigator and Microsoft Internet Explorer issued with enhanced support for multimedia applications

As late as the early 1990s, the Internet was still used primarily by universities and research institutions for communication (e-mail), transferring files (ftp) and related purposes. "User friendliness" was not especially necessary, as almost all users were trained in computer programming and were comfortable with the arcane UNIX commands needed to execute desired tasks. The user interface consisted of a plain text command line; the concept of a graphical user interface for the Internet was still in its infancy. As time went by, however, new Internet services were developed, including email list servers, Gopher, and the World-Wide Web (WWW).

Email list servers allow organized discussion among groups with a particular interest (e.g., artificial intelligence research, invertebrate zoology). Comments posted to the list server by one participant are sent not just to one person (as in regular email), but to all subscribers to the list. Gopher and the WWW have changed the face of the Internet entirely. For the first time, the average Internet user did not need to understand complicated

UNIX commands: it was necessary only to point to the desired item with a mouse or cursor and click. Gopher[e] was developed at the University of Minnesota to enable professors and administrators to make course information available over the network in a simple menu format. Later, the WWW was developed by Tim Berners-Lee at the European Laboratory for Particle Physics (CERN) as a method of sharing information between physicists. WWW documents resemble a printed page in appearance, complete with illustrations and tables. To see more information about a particular item, the user simply clicks on highlighted text with a mouse.

PRESENT AND FUTURE STATUS OF THE INTERNET

Enormous changes to the Internet have taken place over the last three years. Although much of the Internet infrastructure still depends on the UNIX operating system, the development of user ("client") software with a graphical interface has made information much easier to access. Because of this software, Internet users are no longer predominantly technical individuals with programming experience. Most current users have little or no inclination to learn the intricacies of computer programming and operating system command structures, and merely want to use the computer as a tool to achieve a given task.

The most important development in the last few years has been the explosion of activity on the WWW. In fact, the WWW has now become the predominant means by which people access the Internet. The WWW, together with email-related services, constitute the only Internet services of interest to the vast majority of users. The factors underlying the present status include: (1) the evolution of a variety of simple-to-use Web browsers for a number of computer platforms at very reasonable cost, and with support for a number of media formats, (2) the availability of many Internet Service Providers (ISPs) offering Internet services at competitive rates, and (3) the development of numerous new resources on the Web.

These changes represent only the beginning of the next generation of Internet tools. As more people become connected and the "bandwidth," or amount of data that the network can carry, increases, new services will be added at a dizzying rate. Although one cannot predict with certainty what the future has in store for the Internet, it is possible to make some reasonable guesses based on current trends. What follows is a survey of some of the present developments judged likely to strongly influence clinical applications of the World Wide Web and the Internet.

EXPANSION OF THE INTERNET

First, is reasonable to assume that the Internet will continue to grow rapidly in terms of the number of users, the number of Internet Service Providers to support these users, and the Internet resources available. It seems likely that virtually all physicians and most middle-class patients will eventually have Internet access as more resources are made available and as costs continue to drop though market forces. It is even reasonable to expect that some radiologists will arrange get all their X-rays to be interpreted via the Internet. Although this arrangement is practical only with digital X-ray systems, it has the potential to allowing radiologists to continue working while away at a conference or at a sea-side vacation. On the other hand, electronic consultation between physicians and patients using the Internet are likely to develop only to the extent that this activity constitutes a billable service.

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[e]This name is a double pun: "go for," referring to the search function, as well as reference to the gopher as the mascot of the University of Minnesota athletic teams.

Increased Internet speed

It is certain that continual improvements will be made in the speed of Internet access. At the moment, Internet users connecting via telephone are generally limited to a basic data transfer rate of 56 kilobits per second using data compression techniques. Using an ISDN (Integrated Services Digital Network) line, the data transfer rate may be increased to 128 kilobits per second, an improvement of over 100 percent. ISDN services are still in their infancy, however, and suffer from a lack of universal availability, high installation and ongoing costs, and incompatibility between components from different vendors. Fortunately, these problems are gradually being resolved, so that ISDN will soon make the Internet more useful to persons needing to download moderately large quantities of information.

Another exciting development is the interest of the television cable systems in providing even higher bandwidth networking. While not as well-developed as ISDN, cable-based services are expected to provide at least ten times the data transmission capacity of ISDN (over one megabit per second), with the possibility that some systems will even provide sufficient bandwidth to handle real-time full-frame video conferencing. There is little doubt that users in large North American cities who desire the high-bandwidth Internet connections necessary for video and other high-data-rate applications will find a number of cost-effective offerings in the near future. It may be quite some time, however, before such services are brought to the remote communities which may benefit the most from Internet-based telemedicine services.

Talking on the Internet

One new use of the Internet is as a long-distance telephone. The system has a single advantage: low cost long-distance conversation. Many disadvantages are involved: the need to buy a special software package, the need to have a computer with a sound card, microphones and modem and the need for a relatively high performance connection to the Internet (at least 14.4 kbs). Furthermore, the connection is sometimes unidirectional (that is, one person must finish speaking before the other begins). The quality of the speech is mostly poor, about the quality found on CB radio.

An extension of the concept of digital telephony is that of Internet videoconferencing, a computationally intensive technology that requires a Pentium class CPU, a video camera, a video digitizer, special software, and far more bandwidth than for Internet telephony.

In the case of both technologies, current commerial system offerings may be reviewed by visiting the Web sites of the various commercial enterprises as obtained with the use of an Internet search engine (e.g., http://www.excite.com; http://www.lycos.com; http://www.yahoo.com.)ˈ

Proliferation of commercial services

A large number of commercial enterprises have already established a presence on the Internet, usually in the form of a Web page, and one can only expect that the number will continue to increase. Such commercial Web sites usually have an easy to remember URL address, most often in the form: "http://www.'name-of-company'.com" (e.g., http://www.ibm.com, http://www.microsoft.com, and http://www.toyota.com).

Companies frequently use the Internet as a means of providing product information to potential customers or to receive enquiries via email. An increasing number of companies also use the Internet to provide customer services, such as accepting orders and providing technical support. Several companies provide literature-search services for physicians over the Internet, although some services require prior registration.

Making purchases via the Internet is now possible. Indeed, several Internet virtual banking systems exist that can be used to purchase items by mail order. Information such as real-time stock exchange data is available commercially on the Internet and can be paid for using virtual money or by charging to a credit card. In the spirit of Information Philanthropy (*vide infra*) many of these new Web services provide free resources to attract customers, such as real-time stock data (delayed by 20 minutes), or electronic magazine articles about mutual fund selection.

The credit card remains the most common means of conducting Internet commerce. However, not everyone is willing to send unprotected credit card information over the Internet, citing concerns about unauthorized interception of email. Some companies get around this problem by providing a free "800" number to call with credit card information, although similar security concerns exist there as well. Some WWW browsers (e.g., Netscape Navigator 2.0 and later releases (Netscape Navigator and related products can be downloaded from http://www.netscape.com) include features that allow the transmission of encrypted information to enhance security. This feature, however, does not prevent fraudulent use of the credit card information by its intended recipient.

Banking and Financial Services on the Internet

In the last year there has also been enormous growth in the financial and banking services available via the Internet, a reflection of the growing commercialization of the Internet. Many of these providers only use the Internet to offer information about the services they offer, although in some cases a portion of the offered services can also be accessed directly via the Internet instead of by telephone contact or by face-to-face visit. The range of services now available includes the sale and purchase of stocks, mutual funds, bonds, and other financial instruments. Even international currency exchange transactions can be carried out using the Internet.

Financial transactions on the Internet may involve credit card numbers on file, a pre-established credit account, or even "digital cash." For a rich source of further information on this and related topics visit a collection of links provided by InfoRamp, a commercial Internet services provider (http://www2.inforamp.net/iramp/inforamp/business/money.html). Many companies with an Internet presence will accept "digital cash." For example, one can set up an account with First Virtual Corporation that allows payments to be made via the Internet. The account can be replenished as needed by personal check or by credit card or other means, such as a wire transfer. Other virtual financial services firms have been established, including a number of offshoots of classical financial services firms.

INFORMATION PHILANTHROPY

One Internet development of special interest to the academic community is the recent growth of "Information Philanthropy," an arrangement where the author of a particular work retains the copyright to that work, but allows free unrestricted distribution of the work without special permission. This offer is usually made with the proviso that no alterations be made and that all credits remain intact (this is sometimes referred to as "copyleft"). This is similar to, but distinct from, works whose copyright has lapsed (usually 50 years after the death of the author), which are now in the public domain. Project Gutenberg (http://www.w3.org/pub/DataSources/bySubject/Literature/Gutenberg/) is a collection of books, stories, poetry and other resources consisting predominantly of copyright-lapsed works (e.g., Mark Twain's *Tom Sawyer*) with a smattering of copyrighted books provided courtesy of the author's copyleft (e.g., *Zen and the Art of the Internet*).

An example of Information Philanthropy in the world of academic medicine is *Educational Synopses in Anesthesiology and Critical Care Medicine*, an on-line journal of anesthesiology (http://gasnet.med.yale.edu/esia/). This is a peer-reviewed journal with an

international editorial board and a mission to provide high-quality continuing medical educational material to anesthesiologists and acute-care physicians. A number of other such journals also exist. An excellent directory of electronic journals can be found at http://www.med.yale.edu/library/collections/ejournals.html.

CLINICAL SERVICES AND THE INTERNET

There are many ways the Internet might benefit clinical care delivery. Some possible ideas and examples are given below:

1.   A patient to be admitted on the morning of surgery for coronary artery bypass grafting refers to a Web Page one month in advance to check if aspirin should be discontinued preoperatively.

2.   An elderly patient going to Florida for the winter has his medical synopsis and electrocardiogram records stored on a secret Web page, to be accessed only in case of medical emergency. (Of course, he could just as well carry the originals in his briefcase).

3.   A newly diagnosed diabetic woman goes to Diabetes Central, a Web page collection of selected diabetes links, to learn about the kinds of insulin available and how to adjust insulin doses with changes in eating patterns.

4.   A patient wonders whether his operation can be done without general anesthesia, and if so wonders what drugs are involved.

5.   An electronic medical journal is published monthly and distributed free to subscribers by email.

6.   A hospital telephone directory is put on the hospital's home page to save operator costs and encourage patients to use their services.

In the following sections we will explore some of these issues and others in more detail.

Shared medical records

Physicians working together as team members will, in the future, be able to access clinical information about their patient (status of laboratory tests, digitized electrocardiograms and X-rays, etc.) using a Virtual Patient Chart organized just like the current paper record. Using this model, one could, for example, annotate a digitized X-ray as to a possible fracture site (adding a digital arrow) and then send the X-ray file to a radiologist at home, with a request for a quick verbal report by telephone. Lab report copies could be sent automatically to physicians carrying email pagers to insure that clinicians are automatically notified of important clinical developments.

Personal clinical web page

One concept of potential value to patients and emergency room physicians is that of a "Personal Clinical Web Page." This is essentially an entry on the World Wide Web containing personal clinical information of potential value to treating physicians. A working sample Personal Clinical Web Page has been constructed to illustrate the concept (http://www.inforamp.net/~djdoyle/pcwp.html). The system is illustrated conceptually in the following hypothetical scenario. (More information on the concept, including means by which site security could be maintained, is available in a letter to the JAMA [3].)

CLINICAL VIGNETTE

An eldery male is brought to the emergency department in a Florida hospital in an unresponsive state. A quick review of his wallet reveals an Ontario, Canada driver's licence and sufficient cash to cover emergency medical treatment. Also in the wallet is the following card:

Mr. Joseph P. Jones   DOB 1943/12/30
1203 Avenue Road, Toronto, Canada, M7S-1K4
Telephone: 416-555-1265
Medications: Insulin, Digoxin, Diltiazem, Furosemide
Allergies: Previous anaphylaxis to penicillin
Medical Problems: Insulin dependent diabetes for 22 years complicated by pro-teinuria and two myocardial infarcts (the second presenting with congestive heart failure)
For detailed information see http://lifesave.net/jpjones/

While an intravenous is started, oxygen is given and blood samples are drawn for investigation, the emergency room physician asks the emergency room ward clerk to use the ER computer and modem to access the Internet Web address given on the card. There, the physician finds a complete, detailed medical his-tory including details of the last two hospital admissions as well as copies of the patient's latest electrocardiogram and chest X-rays. The electronic chart also notes that Mr. Jones has had a 9 month history of transient ischemic attacks; this datum increases the physician's suspicions that Mr. Jones has had stroke. Remembering some study about the use of calcium channel blockers in acute stroke management, he then requests the ward clerk to search across the Internet to see if the NIH has issued any consensus guidelines on the matter.

CONTINUING MEDICAL EDUCATION (CME) VIA THE INTERNET

The Internet would appear to offer enormous potential for both informal and formal (accredited) Continuing Medical Education (CME). In the category of informal CME, a large number of physician educational resources exist in a variety of specialties, although services for radiology, anesthesiology, critical care medicine and cardiology appear to be especially well represented. A visit to the Medical Matrix Web page of clinical medicine resources (http://www.kumc.edu/mmatrix/index.html) provides an easily accessible and comprehensive list of such resources.

One problem with many of the informal clinical resources on the Internet is the lack of a peer-review process to ensure high quality. Some CME resources on the Internet attempt to fill this gap by publishing material using the classical peer-review process used by academic journals. *Educational Synopses ˙in Anesthesiology and Critical Care Medicine*, mentioned earlier, is a peer-reviewed educational journal that is published monthly and available free-of-charge from the *GASNet* server at Yale University (http://gasnet.med.yale.edu/esia/). Similar journals in other specialties are also under development.

Less well developed than published medical information, however, are formal accred-ited Continuing Medical Education (CME) services using the Internet. Many physicians must complete a number of CME credits annually as a condition to continuing medical licensure. They usually obtain the required credits by attending symposia or courses, or by subscribing to CME newsletters containing a test section that is filled out and correct-ed by a CME service provider.

Several medical schools are developing methods of awarding CME credits over the Internet using the WWW. The user of an Internet-based CME service might go to the Internet CME provider's WWW page, register and pay for services using digital cash or a

credit card. After entering a user code and password, the user then picks a given lesson and either reads it on the spot or saves it for later study. When the material has been digested and the answers to the multiple choice test are completed, the answers may then be entered as "form" entries on a Web page in much the same way one completes a similar paper test. Upon successful completion of block of lessons, a paper certificate of achievement would be sent to the physician, along with an acknowledgment that a record of the new CME credits had been sent to the licensing bodies identified at the time of registration.

MEDICAL COMPUTING VIA THE INTERNET

The use of "forms" in Web pages allows a user to send information to a program running on the Web server. In many applications, form entries are used to enter information such as name and address data or to check off options from a list. However, form techniques can also be used for medical computing over the Internet where form entries are used to enter clinical data such as hemoglobin concentration or urinary sodium concentration. Examples of medical computing applications that can be implemented in this way include the following: calculation of serum osmolality, calculation of the alveolar-arterial oxygen tension gradient, calculation of physiological dead space, or calculation of maintenance intravenous fluid requirements. The software technology known as "Digital Agents" may be used for this purpose.

Digital Agents

Digital Agents are software robots that do a small, restricted job well. Digital Agents such as some of the Internet search engines (e.g., http://www.excite.com, http://www.lycos.com or http://www.yahoo.com) used to search the Web, where the user enters a keyword and the software agent returns URLs (Web site addresses) containing the requested word or phrase. Digital agents could also be used to facilitate job searches for employers; persons seeking employment would register using a registration Web site, while employers would search the pool of registrants using a database reporting system interfaced to a Web browser.

A limited number of clinically-oriented Digital Agents now exist on the Internet. For example, a (mostly debugged) series of experimental Web sites dealing with this field of remote Medical Informatics is available at http://www.physics.utoronto.ca/~jarvis/n.cgi where n is one of the following: 12 for Alveolar Gas Equation, 16 for Measured Creatinine Clearance, 17 for Estimated Creatinine Clearance, 18 for Renal Failure Index, 19 for Renal Free Water Clearance, 20 for Renal Fractional Excretion of Filtered Sodium (FEFNa), and 38 for a Microgram/Kilogram/Minute Drug Infusion Setup. The number n corresponds to the corresponding chapter number in a related book on medical informatics [9].

CONCLUSIONS

Even at this early stage, the Internet is becoming ubiquitous, playing an important role in research, education, and even popular entertainment. Physicians are starting to use the Internet as an aid to clinical and basic research, to collaborate with colleagues, and for patient education. New resources that have become available include peer-reviewed online medical journals, patient-oriented multimedia teaching resources dealing with common ailments, and even distributed virtual textbooks (e.g., one chapter on a server in Toronto, another at Yale). Increases in Internet bandwidth are making real-time telemedicine more promising; such services will allow more use of video conferencing and remote collaborations.

There is no doubt that as the Internet grows and new resources are created it will continue to play an even more important part in medicine.

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GLOSSARY AND ABBREVIATIONS

ARPA	Advanced Research Project Agency. The military agency responsible for the birth of the Internet.
BBN	Bolt, Beranek & Newman (a Cambridge, Massachusetts company)
CERN	The European Laboratory for Particle Physics. The birthplace of the World Wide Web (WWW).
CME	Continuing Medical Education
CPU	Central Processing Unit
Email	Electronic or virtual mail
FTP	File transfer protocol. A means by which electronic files (images, documents) can be transfered from one computer to another.
HTML	Hypertext Markup Language. Language to present information on the World Wide Web.
HTTP	Hypertext Transfer Protocol. Rules governing the exchange of information on the World Wide Web.
ISDN	Integrated Services Digital Network. A digital telephone exchange supporting higher data rates than analog methods.
NSF	National Science Foundation. The main sponsor of the Internet following its break from its military origins.
TCP/IP	Transfer Control Protocol/Internet Protocol. The set of rules describing the transfer of data between computers connected via the Internet.
UNIX	A popular operating system, with commercial and free versions, used frequently on Internet servers.
URL	Universal Resource Locator. An address specifying one or more resources on the Internet (eg, http://www.paranoia.com).
WWW	World Wide Web. A network (web) of computers which exchange information on the Internet using the HTML Web page description language and the HTTP data transmission protocol.